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Description

METHOD AND SYSTEM FOR CONTROLLABLY TRANSFERRING ENERGY FROM A HIGH VOLTAGE BUS TO A LOW VOLTAGE BUS IN A HYBRID ELECTRIC VEHICLE

BACKGROUND OF INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates hybrid electric vehicles having a high voltage bus and a low voltage bus, and in particular, to transferring energy from the high voltage bus to the low voltage bus.

[0003] 2. Background Art

[0004] Many hybrid electric vehicles, such as series, parallel, and parallel-series hybrids, typically include a high voltage bus and a low voltage bus. Typically, the high voltage bus transfers energy between components used to drive the

vehicle and the low voltage bus transfers energy to accessory loads.

[0005] The high voltage bus can be electrically coupled to the low voltage bus by a DC/DC converter, allowing energy to be transferred between the buses. Because the high voltage bus maintains a high voltage, it is typically discharged when the vehicle is not in operation. In doing so, a battery or other high voltage energy storage device coupled to the high voltage bus is isolated from the rest of high voltage bus.

[0006] Commonly, the isolation is achieved by opening contactors used to electrically couple the high voltage energy storage device to the rest of the high voltage bus. The open contactors must then be closed to start the vehicle. Prior to closing the opened contactors, energy is transferred from the high voltage energy storage device to the high voltage bus for precharging the high voltage bus.

[0007] The precharging prevents an instantaneous short from occurring when the contactors eventually close. The precharging ends when the high voltage bus is sufficiently charged and the contractors close.

[0008] After precharging, but before the entire powertrain is enabled, the system waits in a state where the high voltage

bus is enabled but a primary energy source, typically an internal combustion engine or a fuel cell system, is temporarily disabled. This is referred to as "prestart."

[0009] During such prestart, experimental testing indicates some degradation can occur to a low voltage battery coupled to the low voltage bus. In particular, the degradation can occur when the accessory loads powered by the low voltage bus are operated during extended periods of prestart, such as when the ignition key is in the run position and the lights or radio are on. Accordingly, there exists a need to limit such degradation to the low voltage battery.

SUMMARY OF INVENTION

[0010] The present invention meets the need identified above with a method and system for controllably transferring energy from a high voltage bus to a low voltage bus during prestart. In this manner, a low voltage battery coupled to the low voltage bus can receive sufficient energy during precharging to limit degradation.

[0011] One aspect of the present invention relates to a method for operating a hybrid electric vehicle to limit degradation of the low voltage battery. The method generally relates to controllably transferring energy to the low voltage battery using a DC/DC converter.

[0012] In one embodiment of the present invention, the DC/DC converter is coupled between the high and low voltage buses, allowing energy to be controllably transferred between the buses. The method includes controlling the DC/DC convert based on energy available from a high voltage battery coupled to the high voltage bus.

[0013] One aspect of the present invention relates to monitoring the high voltage battery energy level and controlling the DC/DC converter to transfer energy to the low voltage bus. Preferably, energy is only transferred to the low voltage bus if the high voltage battery energy is sufficient for powering an electric starter. This is done to ensure that enough energy is available for the electric starter to start the primary power source.

[0014] One aspect of the present invention relates to a hybrid vehicle system. The hybrid vehicle system includes a vehicle having a high voltage bus and a low voltage bus. An internal combustion engine (primary power source) and a high voltage battery (secondary power source) provide hybrid operation of the vehicle.

[0015] The system further includes a DC/DC converter and a vehicle system controller. Preferably the DC/DC converter is coupled between the high voltage bus and the low voltage

bus. The vehicle system controller includes instructions for controllably transferring energy from the high voltage bus to the low voltage bus during prestart of the high voltage bus by controlling energy flow through the DC/DC converter.

BRIEF DESCRIPTION OF DRAWINGS

[0016] FIG. 1 illustrates an example of a hybrid electric vehicle arrangement for transferring energy between a high voltage bus and a low voltage bus, in accordance with the present invention; and

[0017] FIG. 2 illustrates an example of a control strategy flowchart representing a method for implementation by an electronic control module to control the transfer energy to the low voltage bus, in accordance with the present invention.

DETAILED DESCRIPTION

[0018] The invention described herein is a system and corresponding method for operating a hybrid electric vehicle during prestart of the vehicle's high voltage bus; for example, after an ignition key is turned to a run position during which a primary power source is temporarily deactivated. The method described herein is applicable gener-

ally to any hybrid vehicle system, and is not limited to a specific construction or configuration of the vehicle or its powertrain.

[0019] FIG. 1 shows generally a hybrid vehicle system to which the present invention may be applicable, commonly referred to as a parallel-series hybrid vehicle (PSHEV) system 10. The present invention, however, also relates to other hybrid vehicles (HEVs), including series hybrid electric vehicles (SHEV), parallel hybrid electric vehicles (PHEV), and fuel cell hybrid vehicles (FCHEV).

[0020] The system 10 includes a gasoline-fueled internal combustion engine (ICE) 14, a vehicle system controller (VSC) 16, a high voltage battery 18, and a low voltage battery 20.

[0021] The internal combustion engine 14 and high voltage battery 18 are coupled to the vehicle driveline through an electronic power transmission unit 22 having a first motor/generator 26 and a second motor/generator 28. The first motor/generator 26 functions primarily as a generator and the second motor/generator 28 functions primarily as a motor.

[0022] The high voltage battery 18 series primarily as an energy storage device to store electrical energy produced by the

first motor/generator 26. A high voltage bus 32 couples the first and second motor/generators to the high voltage battery 18. A precharging device 36, controllable by the vehicle system controller 16, provides energy from the battery 18 to the high voltage bus 32 for precharging.

[0023] The internal combustion engine 14 is generally referred to as "the primary power source," and the combination of the high voltage battery 18, motor/generator 26 and motor/generator 28 is collectively referred to as "the secondary power source." It is understood, however, that the primary and secondary sources can be interchanged, and that the invention is not intended to be limited to specific types of vehicular power sources.

[0024] The primary power source, for example, can be any internal combustion engine, including but not limited to gasoline, diesel, hydrogen, methanol, natural gas, ethanol or other gas or liquid-fueled internal combustion engine. Alternatively, the primary power source can be a fuel cell engine, such as a hydrogen-powered fuel cell engine.

[0025] The secondary power source likewise is not limited to a battery and corresponding electrical machines, but may also include ultracapacitors, linear generators and other electro-mechanical or hydraulic devices for generating

torque.

[0026] The power transmission unit 22 includes a planetary gearset 36, which includes a ring gear 38, a sun gear 40 and a planetary carrier assembly 42. The ring gear 38 couples motor/generator to the vehicle drivetrain via step ratio gears/meshing gear elements 42, 44, 46, 48 and 50.

[0027] Sun gear 40 and planetary carrier assembly 42 likewise couple the internal combustion engine 14 and motor/generator 26, respectively, to the vehicle drivetrain (shown as vehicle traction wheels 54, and differential and axle mechanism 56) via a torque output shaft 58 of the power transmission unit 22.

[0028] Gears 44, 46, and 48 are mounted on a countershaft, the gear 46 engaging a motor-driven gear 62. Electric motor 28 drives gear 62, which acts as a torque input for the countershaft gearing.

[0029] Via the VSC 16, the HEV system 10 can be operated in a number of different power "modes" utilizing one or more of the internal combustion engine 14, motor/generator 26 and motor/generator 28. Some of these modes, described generally as "parallel," "split" and "electric," are described for example in United States Patent Application Serial No. 10/248,883, which is owned by the present assignee and

hereby incorporated herein by reference in its entirety.

[0030] One of these modes, the "electric vehicle" (EV) or "electric drive mode," is established when the internal combustion engine 14 is shut off and a one-way clutch 66 engaged for braking torque input shaft 68 and the carrier assembly 42. This leaves the vehicle in EV mode wherein tractive force is delivered only by an electric propulsion system comprised of the high voltage battery 18 and one or both of the motor/generators 26 and motor/generator 28.

[0031] The foregoing, generally, describes the means for driving the vehicle using one or both of the engine 14 (primary power source) and the high voltage battery 18, the first and second motor/generator 26, 28 (secondary power source). In addition, the system 10 can also be used to power accessory loads 70 such as, a radio, CD player, GPS system, lighting, and others, as one of ordinary skill in the art will appreciate.

[0032] The accessory loads 70 are preferably powered via energy delivered over low voltage bus 72. The energy to power the accessory loads 70, in accordance with the present invention, can originate from the low voltage battery 20 or the high voltage bus 32.

[0033] A DC/DC converter 74 is provided to control the transfer

of energy to the low voltage bus 72 from the high voltage bus 32. In this manner, energy from the high voltage battery 18, or energy developed during regenerative braking and delivered to the high voltage bus 32, can be transferred though the DC/DC converter 74 to the low voltage bus 72.

[0034] The DC/DC converter 74 is controllable by the vehicle system controller 16. In general, the vehicle system controller 16 can monitor various system 10 sensors and communicate a control signal to the DC/DC converter 74. In response to the control signal, the DC/DC converter 74 controls the transfer of electrical energy between the high voltage bus 32 and the low voltage bus 72.

[0035] FIG. 2 illustrates a flowchart 78 representing a method for implementation by the electronic control module 16 in accordance with the present invention to controllably transfer energy to the low voltage bus 72.

[0036] A block 80 relates to determining an ignition key turned to a run position. The run position is a key position which activates the vehicle electrical system, but not the engine. Generally, the accessory loads 70 can be used when the ignition key is turned to the run position.

[0037] A block 82 relates to initiating precharging of the high

voltage bus 32 response to block 80 by transferring limited energy to the high voltage bus 32 prior to closing contactors 84. Typically, this is done with a resistive element, not shown, bypassing the contactors 84. The precharging prevents an instantaneous short from occurring in the high voltage bus when the contactors eventually close.

[0038] A block 86 relates to closing contactors 84. The contactors 84 are closed to couple the high voltage battery 18 to the high voltage bus 32. The closed contactors 86 signify the end of precharging. After precharging, but before the entire powertrain is enabled, the system waits in a state in which the high voltage bus is enabled but a primary energy source, typically an internal combustion engine or a fuel cell, is temporarily disabled. This is referred to as a prestart.

[0039] During such prestart, experimental testing indicates some degradation can occur to the low voltage battery 20 coupled to the low voltage bus 72, especially when accessories powered by the low voltage bus 72 are operated during extended periods of precharging, such as when the ignition key is in the run position and the lights or radio are on.

[0040] As described below, the present invention limits such degradation by transferring energy to the low voltage bus 72 during prestart. In this manner, the battery 20, preferably, is prevented from over discharging. Because the over discharging is limited, a smaller battery can be used to save cost, or the battery could be replaced with an ultracapacitor or other energy storage device. The accessory loads can be operational for extended periods during precharging.

[0041] In this manner, energy from the high voltage battery 18 can be used to electrically start the generator/motor 26 and to provide torque for driving the vehicle, if desired. The use of the generator/motor 26 to crank the engine 14 could be performed by another electric starter, especially if a fuel cell is used instead of engine 14.

[0042] A block 88 relates to determining available energy from the high voltage battery 18. The available energy controls how much energy can be transferred to the low voltage bus 72 through the DC/DC converter 74. Preferably, the battery state of charge or the battery discharge power limit are determined. Based on one or more of these energy values, the vehicle system control 18 can determine how much energy can be transferred to the low voltage

bus 72.

[0043] Preferably, the high voltage battery 18 always maintains sufficient energy for powering the generator/motor 26 so that the engine 14 can be cranked. As such, the transfer of energy to the low voltage bus 72 is correspondingly limited, as the energy transferred to the low voltage bus 72 during precharging drains the high voltage battery 18.

[0044] The amount of energy required to power the generator/motor 26 (electric starter) can vary depending on the generator/motor. In addition, the amount of energy required can also vary if the electric starter is another type of starting device or a fuel cell starter, as one of ordinary skill in the art will appreciate.

[0045] A block 90 relates to controlling the DC/DC converter 74 to transfer energy from the high voltage bus to the low voltage bus. This is done by the vehicle system controller 16, or other controller, as one of ordinary skill in the art will appreciate.

[0046] A block 92 relates to checking the energy available from the available battery energy determined in the block 92. A block 94 relates to adjusting the transfer of energy to the low voltage bus 72 based on the available energy determined in block 92. Preferably, the high voltage battery 18

is continuously monitored so sufficient energy is available for the electric starter.

[0047] A block 96 stops further transfer of energy to the low voltage bus 72 if block 74 determines that the available high voltage battery energy is insufficient to keep transferring energy to the low voltage bus 72. This can be determined based on the energy required for the electric starter or other energy requirements for the high voltage system.

[0048] A block 98 relates to checking the low voltage battery 20. Preferably, the low voltage battery 20 is checked to determine if charging is needed. This can include determining the charge of the low voltage battery 20, as well as the rate at which the accessory loads 70 are consuming energy.

[0049] A block 100 relates to powering the necessary loads 70 directly from the energy transferred through the DC/DC converter. This is preferably done once the low voltage battery is sufficiently charged by controlling the DC/DC converter to a voltage higher than the low voltage battery 20.

[0050] A block 102 stops further transfer of energy to the low voltage bus 72 if the low voltage battery is sufficiently

charged and the accessory loads 70 are sufficiently powered.

[0051] A block 104 makes adjustments to the DC/DC converter 74 based on the charge of the low voltage battery 20 and the energy usage of the accessory loads 70. The adjustment can include increasing or decreasing the energy level and the rates of energy transfer.

[0052] A block 106 relates to determining whether the ignition key has been turned to the start position. In the start position, the primary drive source is now activated and the motor/generator 26 (electric starter) begins cranking. If the key is not in the start position, steps 90 through 104 are continuously repeated to maximize utilization of the energy available from the high voltage battery.

[0053] A block 110 relates to ending the prestart energy transfer and a block 112 relates to changing the energy transfer control strategy once the key is turned to the start position. This control strategy can still involve controlling the DC/DC convert and the transfer of energy to the low voltage bus.

[0054] As described above, the present invention provides a method and system for controllably transferring energy from a high voltage bus to a low voltage bus during

precharging. In this manner, a low voltage battery coupled to the low voltage bus can receive sufficient energy during precharging to limit degradation.

[0055] While the best mode for carrying out the invention has been described in detail, those familiar with the art to which this invention relates will recognize various alternative designs and embodiments, and equivalents thereof, for practicing the invention as defined by the following claims.